Design and Construction of the CDF Central Outer Tracker

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Abstract

A new tracking chamber, the Central Outer Tracker (COT), has been built as part of the upgrade of the CDF detector at the Fermilab Tevatron. The COT is a cylindrical open-cell drift chamber, segmented into 96 layers. High voltage and readout electronics are mounted on the chamber endplates, providing timing and charge deposition information. The COT is designed to operate in the high luminosity environment of the upgraded Tevatron. With the addition of the Main Injector and the Recycler Ring, the Tevatron will be capable of provinding luminosity as high as 2×10^{32} cm^{-2} s^{-1} at a bunch spacing of 132 ns. We discuss the design of the detector, as well as the assembly. Construction of the COT was completed in Spring 2000, and the first data will be taken during a commissioning run in late Summer 2000.

1 Introduction

As part of the upgrade of the CDF experiment for Run II (1), all of the tracking detectors are being replaced. The new detector elements and their readout electronics must be capable of handling the high luminosity and high repetition rate provided by the Tevatron. At the beginning of Run II, the bunches will cross at CDF every 396 ns and the luminosity will be as high as 1×10^{32} cm^{-2}s^{-1}. In Run IIb the bunch crossing time will decrease to 132 ns and the luminosity will be as high as 2×10^{32} cm^{-2}s^{-1}.

The central tracking chamber used in CDF until 1996 was known as the CTC. The upgraded design, the Central Outer Tracker (COT), is based on the design of the CTC but improves upon known deficiencies and accomodates the environment in Run II. The COT is a cylindrical open-cell drift chamber spanning from 44 to 132 cm in radii. It operates inside a 1.4 T solenoidal magnetic

field and is designed to find charged tracks in the region $|\eta| < 1.0$ with transverse momentum as low as 400 MeV/c. In addition, the COT is designed to link tracks to segments in the inner silicon detectors, to provide an overall momentum resolution of $\delta p_T/p_T^2 < 0.1\%/\text{GeV/c}$.

2 Mechanical Design of the COT

The COT is segmented into 8 super-layers alternating stereo and axial, with a stereo angle of $\pm 2°$. Each super-layer contains 12 sense wires alternated with 13 potential wires which provide the field shaping within the cell, yielding a total of 96 measurement layers. Unlike a traditional drift chamber where wires are used to complete the field regions, gold-coated mylar cathode planes are used between cells, resulting in a more uniform drift field and reducing both the overall mass of the chamber and the tension on the endplates. The cathode planes are 6.35 μm mylar coated with 450 Å gold, with two stainless steel wires epoxied along the edges of the sheets in a parabolic shape, so that under tension a fraction of the longitudinal tension is transferred to lateral tension by the wires in order to maintain the flatness of the sheets.

The wire planes and field sheets are strung between two precision-machined 1.625" thick aluminum endplates. Slots with precision edges are cut in the endplates to locate the wire planes and field sheets. The endplates are separated by a carbon-fiber composite inner cylinder and an aluminum outer cylinder. The tension on each wire is 150g and on each field sheet is 10kg, resulting in a total endplate load of 40 tons. This load is sufficient to cause a 0.300" deflection in the endplates, a deflection that must be accounted for by pre-tensioning the endplates before installing wire planes and field sheets.

High voltage distribution and readout electronics are both mounted on the chamber face. At one end of the chamber, high voltage motherboards plug onto pairs of wire planes, providing a simple feedthrough from the wire planes. At the other end Amplifier/Shaper/Discriminator (ASD) motherboards connect to pairs of wire planes, providing the connection to the wire planes through decoupling capacitors. High voltage daughterboards plug into the motherboards to provide the connection to the high voltage power supplies. Similarly, ASD daughterboards, holding a custom-built chip for signal processing (2), plug into their motherboards and provide the connection to the TDCs from which chamber signals are readout. The gas seal is made between neighboring motherboards, and between motherboards and the aluminum extrusions that separate the superlayers and distribute low voltage, grounds, and cooling to the electronics.

During running with a 396 ns beam crossing time, the COT will use Argon-

Ethane (50:50), bubbled through isopropyl alcohol. With this gas the drift field in the COT will be 1.9 kV/cm and the maximum drift time will be 180 ns. When the switch is made to 132 ns running, the COT will switch to Argon-Ethane-CF$_4$ (50:35:15). The drift field in this regime will be 2.4 kV/cm and the maximum drift time will be reduced to 100 ns so that tracks from different beam crossings will not overlap in the chamber.

3 Mechanical Assembly

Initial construction of the components of the COT was distributed among collaborating institutions. Wire planes were wound at Fermilab, while universities built field sheets, and the chamber endplates were machined by a commercial vendor. In the first phase of assembly at Fermilab, the endplates were aligned and pre-tensioned. Prior to installing the wire planes and fields sheets, pre-strings were installed to connect corresponding slots on the endplates. Because each wire plane was assembled and installed as a single unit, the pace of stringing of the COT was much faster than it would have been if each wire was strung individually. Stringing began in Jauary 1999 and was completed in May, followed by a period of testing and repair. Following stringing, the extrusions were mounted on the endplates and all motherboards were installed so that the gas seal could be made. Once the gas seal was completed, installation of daughterboards and high voltage testing proceeded in parallel. The completed COT was installed in the solenoid at CDF on 11 May, 2000, and will be ready for the engineering run which will begin in August 2000.

References

[1] The CDF II Detector, Technical Design Report, FERMILAB-Pub-96/390-E (1996).
[2] F.M. Newcomer et al., IEEE Trans on Nucl. Sci. 40 (1993).